

CLAIMS

1. A method of moving a body comprising:

coupling a plurality of piezoelectric motors to the body by pressing a coupling region of each of the motors to a surface of the body;

5 controlling at least one of the motors to apply a force parallel to the surface to move the body; and

simultaneously controlling at least one of the motors so that its coupling region executes only vibrations that are substantially perpendicular to the surface.

10 2. A method according to claim 1 wherein controlling a motor to apply a force parallel to the surface comprises controlling the motor so that the coupling region of the motor vibrates with a component of vibration parallel to the surface.

15 3. A method according to claim 2 and comprising controlling the motor so that the coupling region simultaneously vibrates with a component of vibration perpendicular to the surface of the body.

4. A method according to any of claims 1-3 wherein each motor comprises electrodes that are electrified to control its operation.

20 5. A method according to any of claims 1-4 wherein controlling the motor to apply a force parallel to the surface comprises electrifying at least one of the electrodes with a pulsed voltage.

25 6. A method according to claim 4 or claim 5 wherein controlling the motor to apply a force parallel to the surface comprises electrifying at least one of the electrodes with a DC voltage.

30 7. A method according to any of claims 1-6 and comprising mounting the moveable body to a support structure that constrains it to be selectively moveable along either of a first direction and a second direction.

8. A method according to claim 7 wherein coupling the plurality of motors comprises coupling at least some of the motors so that they are controllable to apply force to the surface

along the first direction and some of the motors so that they are controllable to apply force to the body along the second direction.

9. A method according to any of claims 1-6 and comprising mounting the body to a support structure that enables the body to be freely moved along any direction parallel to a same plane.

10. A method according to claim 9 wherein coupling the plurality of motors comprises coupling a first pair of motors controllable to apply force to the surface along a first direction parallel to the plane and a second pair of motors controllable to apply force to the surface along a second direction parallel to the plane.

11. A method according to claim 10 and comprising controlling the first or second pair of motors to apply forces to the surface that move the body in the first or second direction respectively and controlling the motors so that a net torque resulting from the forces is substantially equal to zero.

12. A method according to claim 11 and comprising controlling a first one of the motors so that its contact region is in constant contact with a particular region of the surface of the body so that the at least one motor that applies a force parallel to the surface generates a torque that rotates the body about the particular region.

13. A method according to claim 7 or claim 8 and comprising controlling the motors in a pair of motors to generate a torque that rotates the body about a point along a line that passes through the contact regions of the two motors.

14. A method according to any of the preceding claims wherein at a first position of the body the plurality of motors comprises at least one motor not comprised in the plurality of motors at a second position of the body.

30

15. A method according to claim 14 and comprising controlling at the first position at least one motor not comprised in the plurality of motors at the second position to apply a force parallel to the surface.

16. Apparatus for moving a body comprising:
a plurality of piezoelectric motors; and
a controller that controls at least one of the motors to apply a force parallel to the surface to move the body and simultaneously controls at least one of the motors to execute only vibrations that are substantially perpendicular to the surface.
- 5
17. Apparatus according to claim 16 wherein the surface of the body is planar.
18. Apparatus according to claim 17 and comprising:
10 a first support structure coupled to the body that enables the body to move freely only along a first direction parallel to the planar surface; and
a second support structure coupled to the first structure that allows the first structure to move freely only along a second direction parallel to the planar surface;
wherein at least one of the motors is controllable to apply a force parallel to the surface
15 along the first direction and at least one of the motors is controllable to apply a force parallel to the surface along the second direction.
19. Apparatus according to claim 16 and comprising a plurality of bearings on which the flat surface lies that enables the surface to move freely in any direction parallel to the surface.
- 20
20. Apparatus according to claim 19 wherein the plurality of motors comprises at least one set of four motors comprising a first pair of motor controllable to apply force to the surface along a first direction and a second pair of motors controllable to apply force to the surface along a second direction.
- 25
21. Apparatus according to claim 20 wherein to move the body along the first or second direction the controller controls the first or second pair of motors respectively so that a net torque resulting from the forces the motors apply to the surface is substantially equal to zero.
- 30
22. Apparatus according to claim 21 wherein the controller controls at least one motor so that its contact region constantly contacts a particular region of the surface and wherein the force applied by the at least one motor parallel to the surface rotates the surface about the particular region.

23. Apparatus according to any of claims 19-22 wherein the controller controls the first pair of motors or the second pair of motors to generate a torque that tends to rotate the surface about a point along a line that passes through the coupling regions of the motors.

5 24. Apparatus according to claim 16 wherein the surface is a circularly cylindrical surface having an axis of rotation.

10 25. Apparatus according to claim 24 wherein at least one motor is controllable to apply a force parallel to the surface that tends to rotate the cylindrical surface about its axis of rotation and at least one motor is controllable to apply a force parallel to the surface that tends to translate the surface along its axis of rotation.

26. Apparatus according to claim 25 wherein the surface is a spherical surface having a center.

15

27. Apparatus according to claim 26 wherein at least one motor is controllable to apply a force parallel to the surface that tends to rotate the surface about a first axis that passes through the center and at least one motor is controllable to apply a force parallel to the surface that tends to rotate the surface about a second axis that passes through the center.

20

28. Apparatus according to any of claims 16-27 wherein at a first position of the body the plurality of motors comprises at least one motor not comprised in the plurality of motors at a second position of the body.

25

29. Apparatus according to claim 28 wherein at the first position the controller controls at least one motor not comprised in the plurality of motors at the second position to apply a force parallel to the surface.